REPORT No. 306

FULL-SCALE WIND-TUNNEL TESTS OF A SERIES OF METAL PROPELLERS ON A VE-7 AIRPLANE

By FRED E. WEICK
Langley Memorial Aeronautical Laboratory

REPORT No. 306

FULL-SCALE WIND-TUNNEL TESTS OF A SERIES OF METAL PROPELLERS ON A VE-7 AIRPLANE

By Fred E. Weick

SUMMARY

An adjustable blade metal propeller was tested at five different angle settings, forming a series varying in pitch. The propeller was mounted on a VE-7 airplane in the Twenty-Foot Propeller Research Tunnel of the National Advisory Committee for Aeronautics. The efficiencies were found to be from 4 to 7 per cent higher than those of standard wood propellers operating under the same conditions. The results are given in convenient form for use in selecting propellers for aircraft.

INTRODUCTION

It has been known for some time that, in general, thin metal propellers are somewhat more efficient than wooden ones. Actual comparative values have not, however, been available. The present full-scale tests on a series of metal propellers give, for the first time, data on the aerodynamic characteristics of full-size metal propellers, and make possible a direct comparison between the metal propellers and a series of wooden propellers tested under the same conditions.

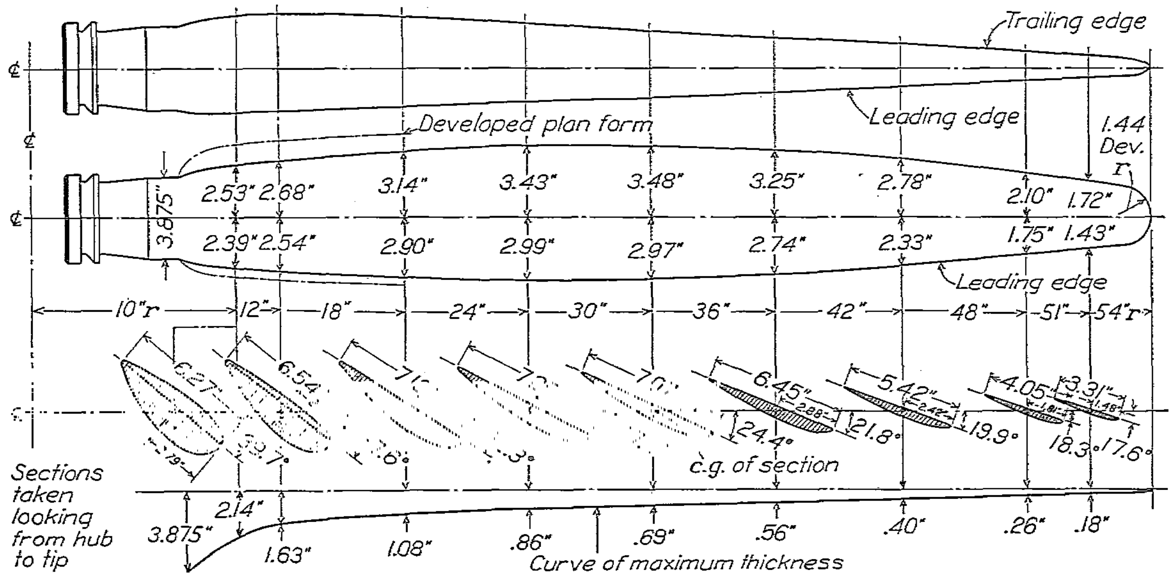

Fig. 1.—Metal blade for 9 ft. diameter propeller. Right hand. No. 4412

A two-bladed adjustable pitch metal propeller was tested at five different blade settings, giving in reality a series of propellers varying in pitch. Since each blade as a whole was rotated in the hub to the desired setting, all of the angles along the blade varied the same amount, so that the pitch did not change uniformly. It is, however, common practice to design detachable blade metal propellers with a certain distribution of blade angles and then turn the blades to any pitch required for a particular airplane, thus facilitating production.

The tests were made on a Vought VE-7 airplane with a 180 HP. Wright E-2 engine, in the Twenty-Foot Propeller Research Tunnel of the National Advisory Committee for Aeronautics, at Langley Field, Va.

METHODS AND APPARATUS

The propeller blades and hub used in this investigation were furnished by the Navy Department. The blades were made of aluminum alloy, according to the drawing in Figure 1. The hub to which they were fitted was of steel, and in order to save weight, had been made 1 inch shorter than the hub for which the blades had been designed, so that while the drawing shows a 9-foot propeller, the diameter in these tests was actually 8 feet 11 inches. The pitch distribution was unusual and is worthy of note. With the blade set at 13° at the 42-inch radius, the pitch from the 36-inch radius to the tip had the approximately uniform value of 5 feet. From the 36-inch radius toward the hub it gradually reduced so that at the 18-inch radius it was only 4.5

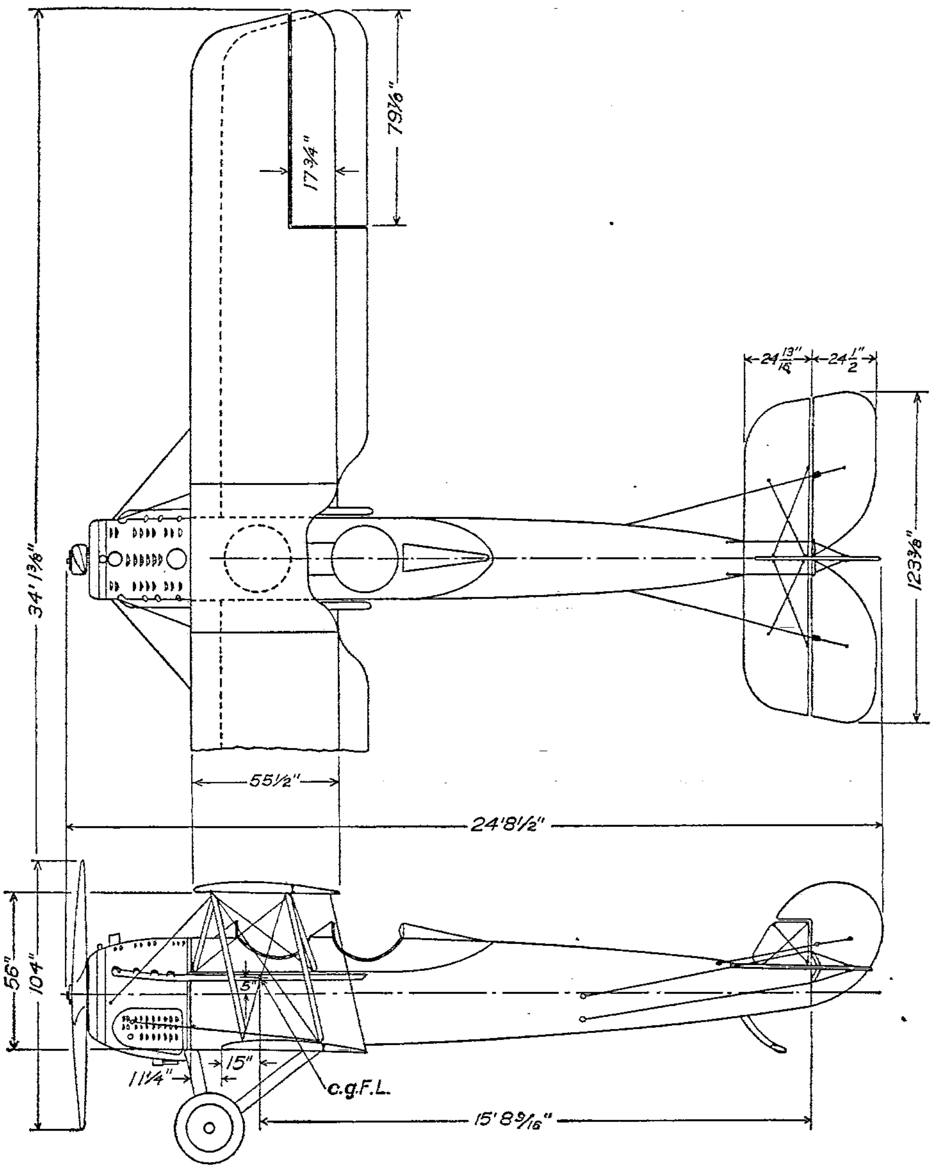

FIG. 2.—Elevational and plan views of the VE-7 airplane

feet. The center line of the propeller, as mounted on the airplane, was 5 inches from the front of the radiator.

The propeller research tunnel is of the open-jet type with an air stream 20 feet in diameter in which velocities up to 110 M. P. H. can be obtained. A complete description of the tunnel, balances, and other measuring devices is given in reference 1.

The VE-7 airplane (fig. 2) had a span of 34 feet, so that when mounted in the air stream the wings projected approximately 7 feet into the relatively still air of the experiment chamber. Figure 3 shows the airplane mounted in the tunnel. It is considered that a sufficient portion of the wing structure was in the air stream to include all parts which would be influenced by or react on the propeller.

The VE–7, as mounted in the tunnel, had inclosed within it a special steel skeleton fuselage with a built-in dynamometer, including a Toledo scale, to measure the engine and propeller torque directly. (Reference 1.)

The revolution speed of the engine was measured by means of a special calibrated Elgin chronometric tachometer, and the velocity of the air stream was obtained by means of calibrated static plates in the return passages leading to a manometer in the experiment chamber.

In order to know the pitch of the propellers while in operation, the deflection of one blade was measured at the 42-inch radius by means of a telescope mounted on a graduated base and sighted on first the leading and then the trailing edge. This was done while the propeller was standing still and then was repeated for each test point while the propeller was running.

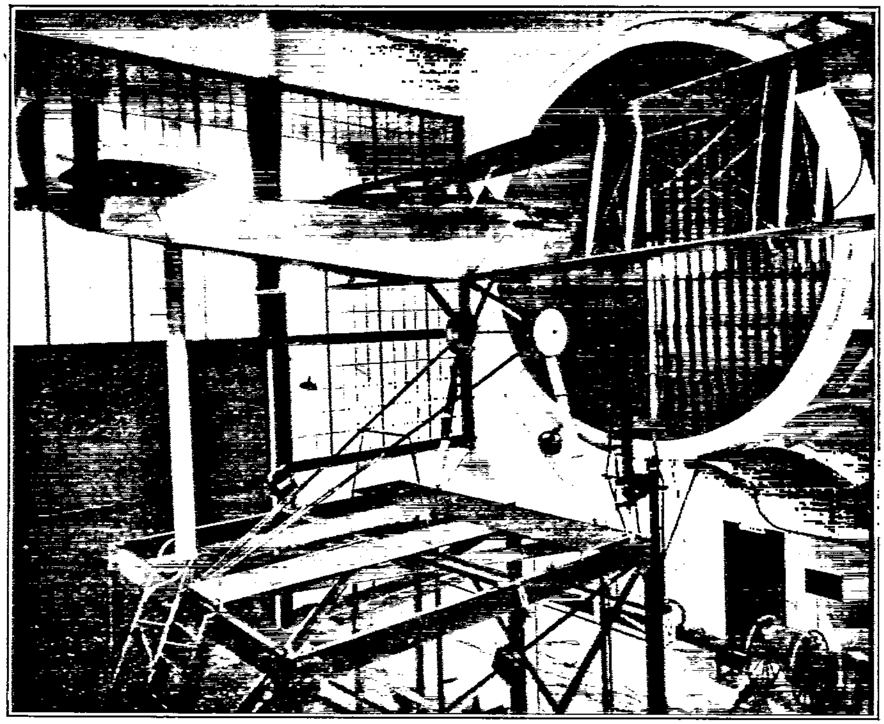

FIG. 3.—VE–7 airplane mounted in Propeller Research Tunnel

The resultant horizontal force of the propeller-body combination, which may be either a thrust or a drag, was measured on the regular thrust balance. (Also described in reference 1.)

This resultant horizontal force, R, may be thought of as composed of three horizontal components, such that

$$R = T - D - \triangle D,$$

where

T = the thrust of the propeller while operating in front of the body (the tension in the crank shaft).

D = the drag of the airplane alone (without propeller) at the same air velocity and density.

$\triangle D$ = the increase in drag of the airplane with propeller, due to the slip stream.

In order to obtain the propulsive efficiency, which includes the propeller-body interference, an effective thrust is used, which is defined as

$$\text{Effective thrust} = T - \triangle D = R + D.$$

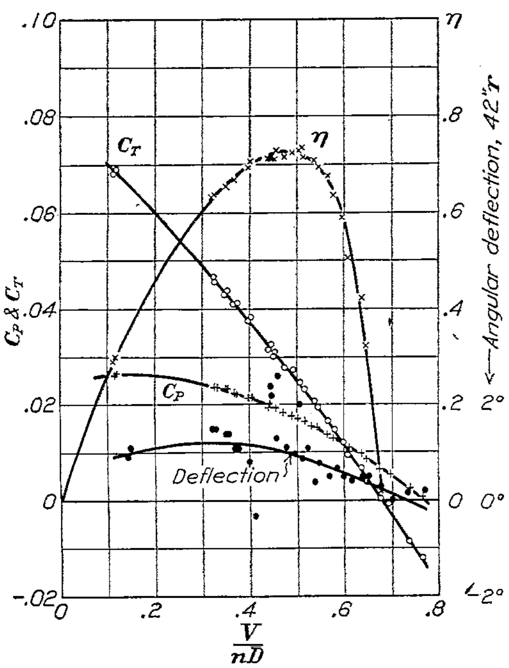

FIG. 4.—Propeller 4412 (11° at 42") on VE-7 airplane

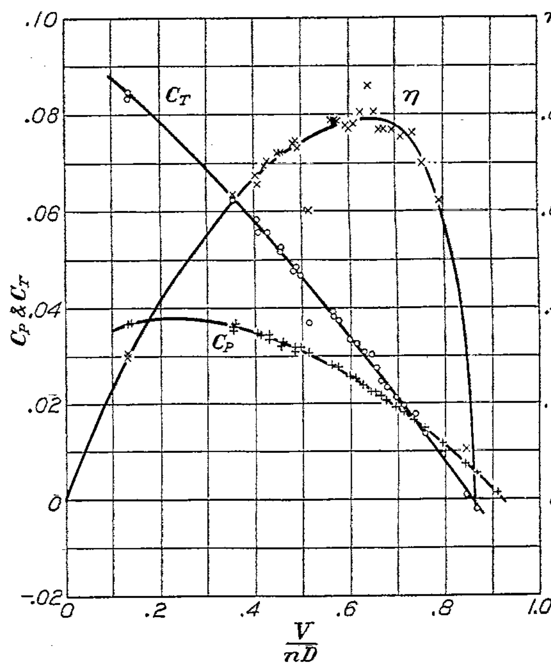

FIG. 5.—Propeller 4412 (15° at 42") on VE-7 airplane

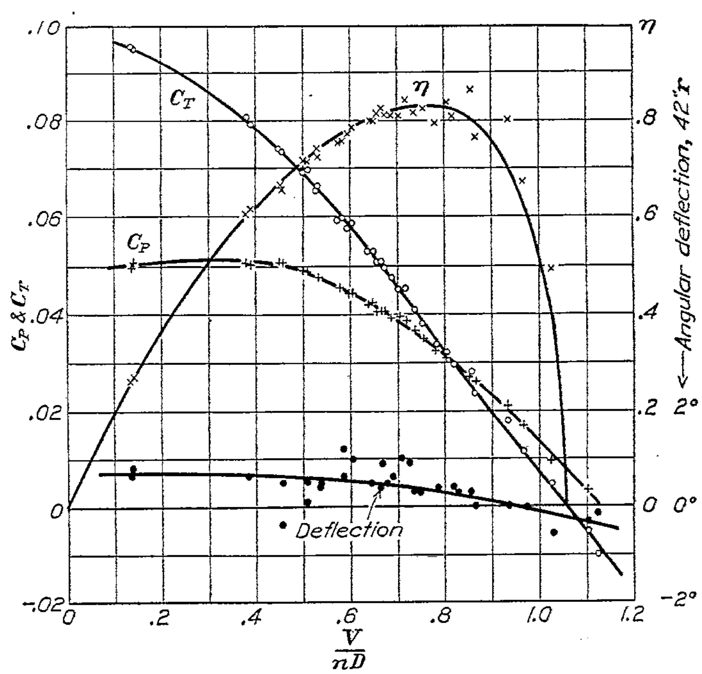

FIG. 6.—Propeller 4412 (19° at 42") on VE-7 airplane

The propulsive efficiency, then, is the ratio of the useful power to the input power, or

$$\text{Propulsive efficiency} = \frac{\text{effective thrust} \times \text{velocity of advance}}{\text{input power}}.$$

This propulsive efficiency includes the increase in drag of all parts of the airplane affected by the slip stream and also the effect of the body interference on the propeller thrust and power.

RESULTS

The observed data points are plotted in Figures 4 to 8, inclusive. They are reduced to the usual coefficients of thrust, power, and propulsive efficiency,

$$C_T = \frac{\text{Effective Thrust}}{\rho\, n^2\, D^4},$$

$$C_P = \frac{\text{Input power}}{\rho\, n^3\, D^5},$$

$$\eta = \frac{\text{Effective thrust} \times \text{velocity of advance}}{\text{Input power}},$$

where D is the propeller diameter and n represents the revolutions per unit time. Since the coefficients are dimensionless, any homogeneous system of units may be used.

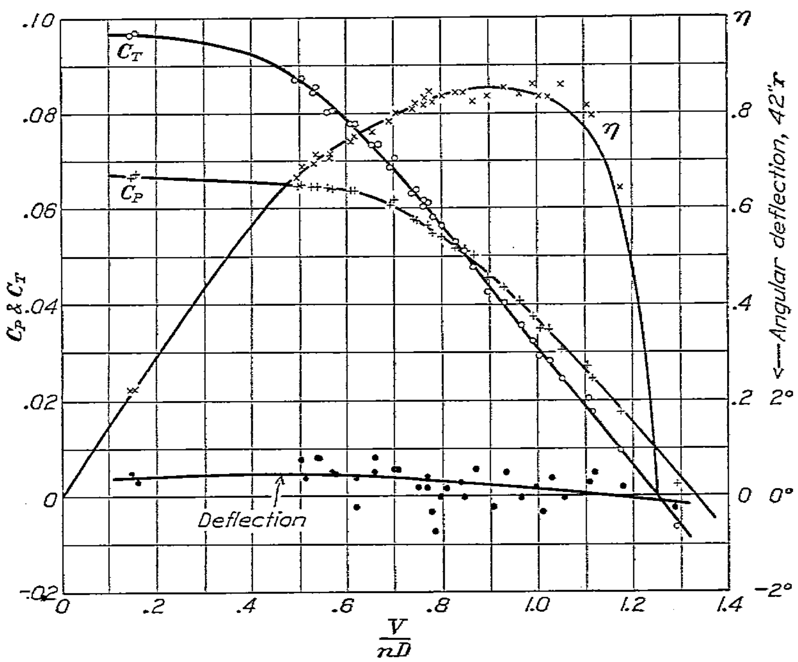

FIG. 7.—Propeller 4412 (23° at 42") on VE-7 airplane

The angular deflections of the propeller blades at the 42-inch radius, which were measured for each test condition, are also plotted in Figures 4 to 8. The blades deflected so as to increase the pitch for all cases excepting the 15° setting. For that setting the deflection readings are evidently erroneous, and have been omitted. For all excepting the 15° setting the twist in operation is greater for the low pitches and the low values of $\frac{V}{n\,D}$. With the highest pitch setting there is practically no twist at any $\frac{V}{n\,D}$.

The curves of thrust coefficients against $\frac{V}{n\,D}$ are given for all of the pitch settings in Figure 9, and similar sets of curves for the power coefficients and efficiencies in Figures 10 and 11, respectively. The curves for the various pitch settings form regular series with no unusual features, except for the propulsive efficiencies which are slightly higher than might have been expected from model tests.

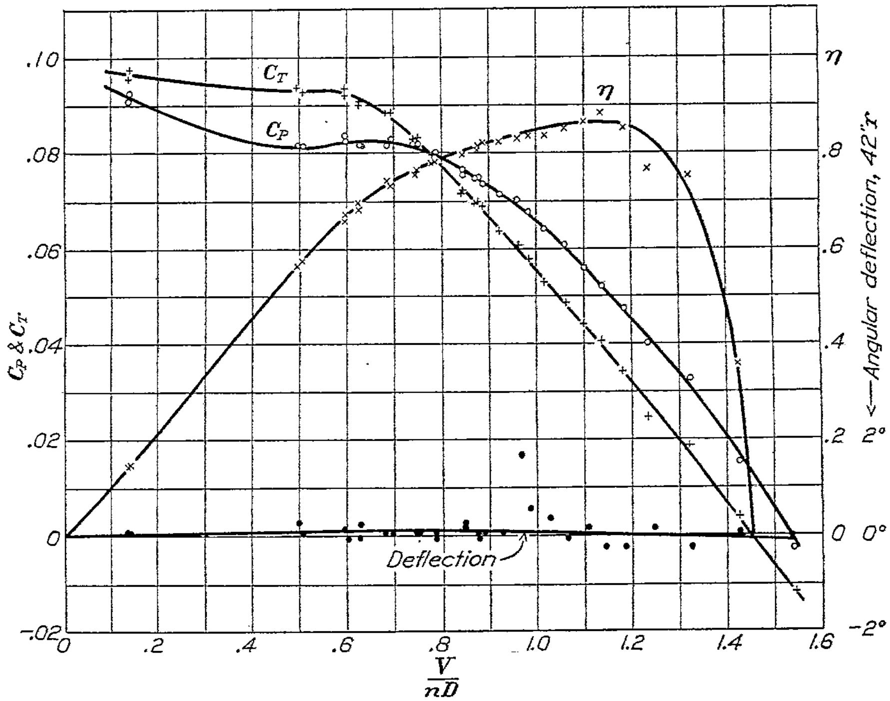

FIG. 8.—Propeller 4412 (27° at 42") on VE-7 airplane

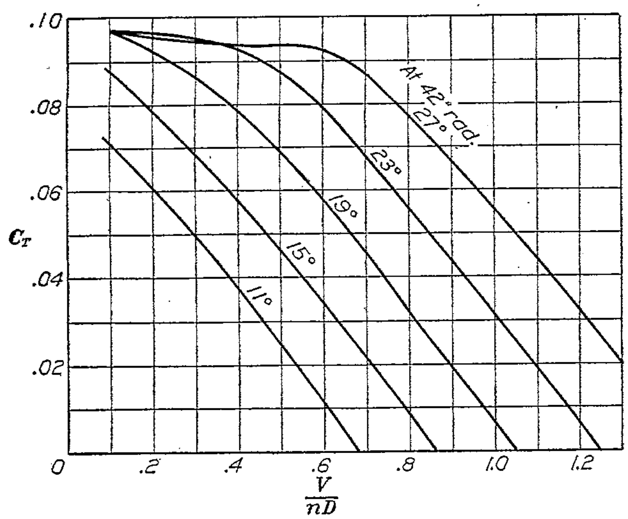

FIG. 9.—Propeller 4412 on VE-7 airplane. Thrust coefficients

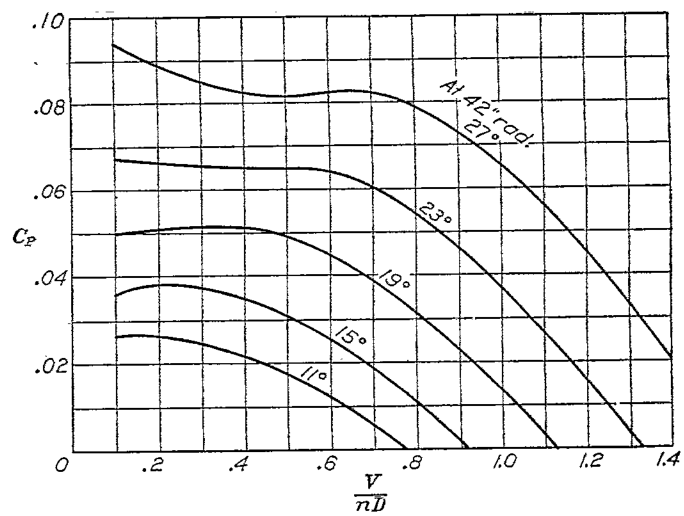

FIG. 10.—Propeller 4412 on VE-7 airplane. Power coefficients

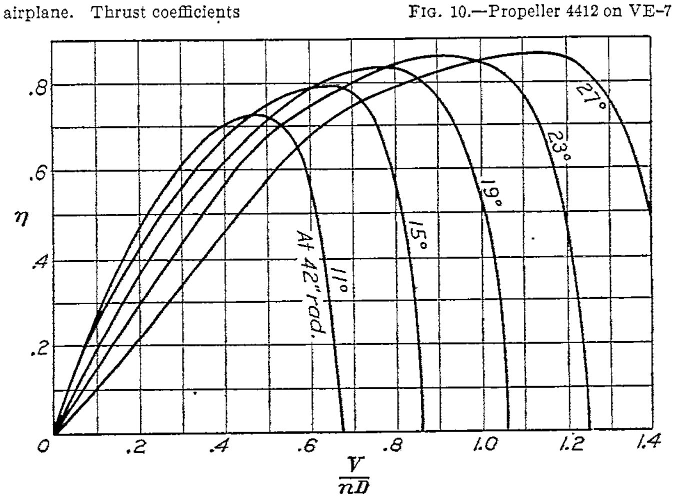

FIG. 11.—Propeller 4412 on VE-7 airplane. Efficiencies

COMPARISON WITH WOOD PROPELLERS

In Figure 12 the efficiencies of these thin-bladed metal propellers are compared with those of a series of three wood propellers varying in pitch ratio. The wood propellers were of Navy form with uniform pitch, and had pitch ratios of 0.6, 0.7, and 0.8. They were tested (Reference 2) on the same *VE–7* airplane and under the same conditions as the metal propellers. The efficiencies are plotted against the coefficient

$$C_S=\sqrt[5]{\frac{\rho\, V^5}{P\, n^2}},$$

where P represents the power absorbed by the propeller. Propellers operating at the same values of C_S are fulfilling the same requirements of power, velocity, and revolutions, and are therefore on a fair basis for the comparison of efficiencies.

Figure 12 shows that the metal propellers are from 4 to 7 per cent more efficient than the wood propellers under the same operating conditions.

USE OF RESULTS IN DESIGNING PROPELLERS

The results of these tests may be used to select the best diameter and pitch setting of propellers of geometrically similar form, to fulfill certain requirements on an airplane having proportions and shape similar to the *VE–7*. The selection can be performed very easily by means of Figure 13, in which the efficiencies and values of $\frac{V}{n\,D}$ for the various pitch settings are plotted against the coefficient C_S. It is erely necessary to (1) calculate the value of C_S for the power, revolutions, and forward speed at which the propeller is to operate, (2) choose the pitch setting for the propeller operating at the desired portion of the efficiency curve, (3) find the $\frac{V}{n\,D}$ for the above C_S and pitch setting from the lower curves, and (4) knowing $\frac{V}{n\,D}$, n, and V, calculate D.

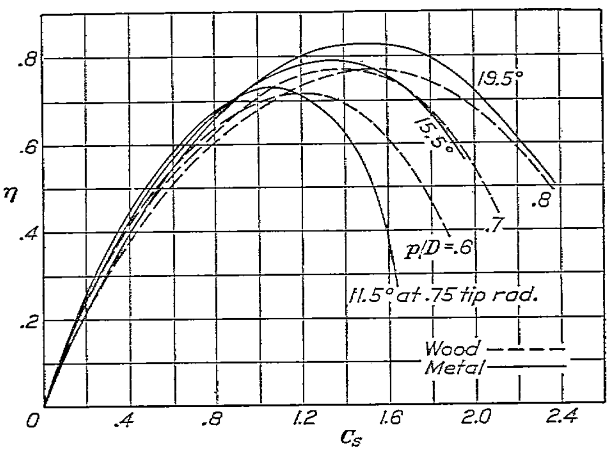

FIG. 12.—Comparison of efficiencies of wood and metal propellers

If the diameter of the propeller is fixed to start with, $\frac{V}{n\,D}$ is also fixed, and the pitch setting can be found directly from the curves of $\frac{V}{n\,D}$ vs. C_S.

Example.—A propeller is to be selected for an airplane similar in form to the *VE–7*. With an engine developing 300 HP. at 1,800 R. P. M., the maximum horizontal speed is expected to be 150 M. P. H.

(1) In engineering units,

$$C_S=\frac{.638\times \text{M. P. H.}}{\text{HP}^{1/5}\times \text{R. P. M.}^{2/5}}$$
$$=\frac{.638\times 150}{3.13\times 20.05}$$
$$=1.52$$

The values of $\text{HP}^{1/5}$ and $\text{R. P. M.}^{2/5}$ can be easily obtained from scales provided for the purpose in Figure 14.

(2) It will be assumed that it is desirable to have the propeller operate at its maximum efficiency at the high speed of the airplane. Then from the upper or efficiency curves of Figure 13, it will be seen that a setting of 19.5° at 0.75 of the tip radius satisfies this condition (i. e., the efficiency curve for the 19.5° setting peaks at C_S = approximately 1.52).

(3) From the lower curves in Figure 13, for $C_S=1.52$ and a setting of 19.5°, $\frac{V}{n\ D}=0.77$.

(4)

$$D=\frac{88\times \text{M. P. H.}}{\text{R. P. M.}\left(\frac{V}{n\ D}\right)}$$

$$=\frac{88\times 150}{1{,}800\times 0.77}$$

$$=9.52 \text{ ft.}$$

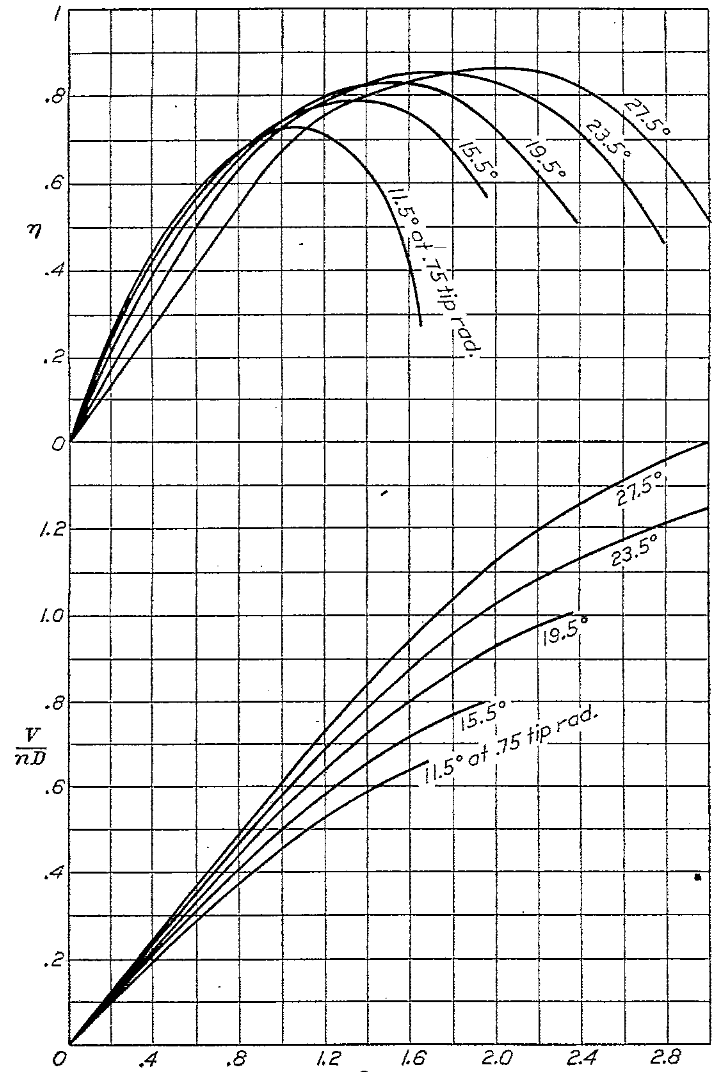

FIG. 13.—Working chart for selecting similar propellers

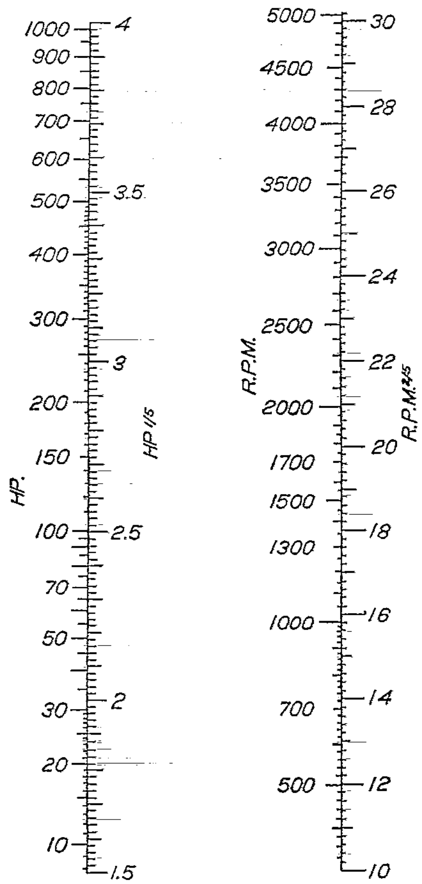

FIG. 14.—Scales for finding $HP^{1/5}$ and R. P. $M.^{2/5}$

The propulsive efficiency, which includes the increased drag of the parts of the airplane in the slip stream, is .83.

In case the diameter were fixed from the start at, say, 9 feet, the $\frac{V}{n\ D}$ would be fixed at

$$\frac{V}{n\ D}=\frac{88\times \text{M. P. H.}}{\text{R. P. M.}\times \text{D}}$$

$$=\frac{88\times 150}{1{,}800\times 9}$$

$$=.815.$$

Then from the lower curves of Figure 13, for $C_S=1.52$ and $\frac{V}{n\,D}=0.815$, the blade angle should be set to 22.0° at 0.75 tip radius.

In the application of these results to the selection of a propeller for an airplane it is essential that the actual brake horsepower of the engine under flight conditions be used in the formula for C_S. The power developed by an engine in service is likely to vary widely from the power developed under ideal conditions on a dynamometer. In a series of 15 flight-performance tests, in which the powers absorbed by the propellers were calculated on the basis of the present full-scale wind-tunnel test data, the computed power averaged about 90 per cent of that credited to the engines by the dynamometer tests on similar engines.

CONCLUSIONS

1. The efficiencies of this series of metal propellers range from 4 to 7 per cent higher than those of standard wood propellers operating under the same conditions (tip speeds up to 800 feet per second).
2. The efficiencies of the metal propellers were rather high, reaching 86 per cent for the highest pitch setting, and were apparently not adversely affected by the pitch distributions obtained by turning the whole blade as a unit.
3. The results of the tests, as presented, may be conveniently used for the selection of a propeller to give a certain performance on airplanes similar to the VE–7.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., *July 13, 1928*.

REFERENCES

1. Weick, Fred E. and Wood,, Donald H.: The Twenty-Foot Propeller Research Tunnel of the National Advisory Committee for Aeronautics. N. A. C. A. Technical Report No. 300 (1928).
2. Weick, Fred E.: Full Scale Tests of Wood Propellers on a VE–7 Airplane in the Propeller Research Tunnel. N. A. C. A. Technical Report No. 301 (1928).

TABLE I

METAL PROPELLER ON VE-7

(PROP. No. 4412)

(BLADE ANGLE 11° AT 42″ r.)

ρ	V M. P. H.	N R. P. M.	Q lb. ft.	T lb.	C_T	C_P	$\frac{V}{nD}$	η	Def. at 42″ Rad., degrees
0.002337	80.7	1820	372	428	0.0319	0.0196	0.440	0.713	+2.4
.002337	81.4	1825	382	438	.0325	.0200	.441	.716	2.2
.002335	85.1	1845	377	425	.0308	.0193	.457	.730	2.6
.002335	85.0	1855	377	423	.0302	.0191	.453	.716	1.3
.002330	94.5	1910	368	386	.0262	.0177	.491	.727	1.0
.002325	90.7	1895	373	401	.0276	.0182	.474	.717	1.1
.002323	99.0	1940	362	370	.0244	.0169	.505	.731	2.0
.002323	99.4	1940	363	371	.0245	.0169	.507	.734	.9
.002320	99.3	1900	343	337	.0232	.0167	.517	.718	1.1
.002317	99.3	1835	296	277	.0204	.0154	.535	.709	.4
.002317	99.1	1805	280	254	.0194	.0151	.543	.696	.8
.002317	98.8	1730	237	200	.0166	.0139	.565	.676	.5
.002317	99.0	1695	213	167	.0145	.0131	.578	.638	.7
.002317	98.8	1645	187	131	.0121	.0123	.595	.591	.5
.002317	98.5	1600	159	94	.0091	.0110	.609	.507	.4
.002317	98.5	1545	135	64	.0067	.0100	.631	.421	.5
.002317	98.0	1505	112	40	.0044	.0087	.645	.325	.5
.002317	97.6	1435	77	2	.0002	.0066	.673	.023	.3
.002315	97.5	1385	56	−26	−.0030	.0052	.696	----------	.0
.002315	98.1	1325	27	−59	−.0084	.0027	.733	----------	.2
.002315	98.8	1285	7	−81	−.0122	.0007	.761	----------	+.2
.002320	75.5	1865	427	533	.0381	.0216	.401	.707	−.3
.002320	75.1	1870	426	529	.0375	.0215	.397	.692	+.8
.002320	68.5	1845	435	562	.0410	.0225	.368	.670	1.1
.002323	68.7	1845	436	562	.0410	.0226	.3685	.670	1.0
.002320	64.6	1815	435	578	.0437	.0232	.352	.663	1.4
.002320	64.3	1820	435	581	.0435	.0232	.350	.657	1.4
.002325	58.9	1800	437	604	.0462	.0237	.324	.632	1.5
.002325	58.9	1800	437	604	.0462	.0237	.324	.632	1.5
.002330	20.0	1735	449	839	.0688	.0262	.1143	.300	1.1
.002330	19.9	1740	450	837	.0684	.0262	.1134	.297	.9

TABLE I—Continued

15° AT 42″

ρ	V M. P. H.	N R. P. M.	Q lb. ft.	T lb.	C_T	C_P	$\frac{V}{nD}$	η	Def. at 42″ Rad., degrees
0.002370	82.1	1655	496	527	0.0468	0.0312	0.492	0.737	−0.1
.002370	82.1	1655	499	528	.0468	.0315	.492	.734	−.6
.002370	86.3	1660	491	407	.0358	.0306	.514	.601	−1.4
.002365	95.6	1685	464	460	.0394	.0282	.562	.786	−.6
.002360	95.5	1680	459	448	.0388	.0279	.562	.788	−.6
.002360	99.2	1710	461	447	.0373	.0272	.574	.788	−.4
.002360	99.1	1705	462	446	.0374	.0274	.575	.786	−.6
.002355	98.9	1635	396	364	.0333	.0256	.600	.780	−.9
.002355	98.8	1600	372	342	.0327	.0252	.612	.783	−.8
.002355	98.6	1555	336	306	.0309	.0240	.628	.806	−.6
.002355	98.1	1505	296	279	.0302	.0226	.645	.862	−.2
.002355	98.4	1495	286	250	.0272	.0221	.652	.803	+.1
.002355	98.1	1435	243	196	.0233	.0204	.677	.773	−.4
.002350	98.4	1465	264	217	.0248	.0214	.665	.770	−.3
.002350	98.3	1395	216	171	.0213	.0193	.699	.771	+.1
.002350	98.3	1365	196	148	.0195	.0182	.712	.759	−.3
.002350	98.0	1325	171	127	.0177	.0169	.733	.766	−.1
.002350	97.8	1280	141	92	.0138	.0149	.757	.700	−.8
.002350	97.8	1225	102	57	.0093	.0118	.791	.626	−.3
.002350	97.4	1145	56	5	.0010	.0074	.842	.1071	−.2
.002350	97.2	1110	41	−11	.0022	.0058	.864	----------	−.8
.002350	97.3	1060	9	−36	----------	.0014	.910	----------	−.7
.002350	97.0	990	−26	−72	----------	----------	----------	----------	−.3
.002360	81.1	1645	494	537	.0484	.0316	.488	.748	+.1
.002360	81.1	1660	497	541	.0478	.0311	.484	.743	−.2
.002360	75.7	1640	511	576	.0523	.0328	.457	.729	−.3
.002360	75.7	1645	511	574	.0517	.0326	.456	.723	−.4
.002360	69.6	1605	506	589	.0558	.0339	.429	.706	+.1
.002360	69.5	1605	509	588	.0557	.0341	.428	.699	−.8
.002360	66.1	1605	515	588	.0557	.0345	.408	.659	−.9
.002360	65.2	1595	511	605	.0581	.0348	.405	.677	−1.2
.002360	56.0	1565	515	637	.0635	.0363	.354	.621	−.3
.002360	56.9	1580	517	651	.0636	.0358	.356	.633	−.4
.002370	20.1	1565	521	853	.0847	.0368	.135	.311	−.4
.002370	20.1	1565	521	842	.0836	.0368	.135	.308	----------

TABLE I—Continued

19° AT 42″

ρ	V M. P. H.	N R. P. M.	Q lb. ft.	T lb.	C_T	C_P	$\frac{V}{nD}$	η	Def. at 42″ Rad., degrees
0. 002350	82. 0	1405	517	481	0. 0594	0. 0455	0. 578	0. 754	+0. 6
. 002350	82. 2	1405	517	481	. 0594	. 0455	. 579	. 755	1. 2
. 002345	87. 0	1430	527	486	. 0585	. 0448	. 602	. 786	1. 0
. 002345	86. 9	1435	529	483	. 0576	. 0447	. 599	. 772	----------
. 002340	95. 5	1465	525	462	. 0527	. 0425	. 645	. 799	. 5
. 002340	95. 4	1475	525	464	. 0525	. 0420	. 640	. 799	----------
. 002340	99. 7	1495	522	460	. 0507	. 0407	. 664	. 826	. 9
. 002340	99. 3	1495	523	457	. 0503	. 0407	. 658	. 814	. 4
. 002340	99. 5	1465	502	431	. 0494	. 0407	. 673	. 815	. 5
. 002335	99. 2	1430	467	392	. 0471	. 0398	. 687	. 811	. 6
. 002335	99. 3	1400	438	358	. 0450	. 0391	. 702	. 809	1. 0
. 002335	99. 1	1365	412	340	. 0451	. 0386	. 719	. 841	. 9
. 002335	98. 4	1325	367	291	. 0407	. 0366	. 734	. 818	. 3
. 002335	98. 9	1295	330	257	. 0377	. 0344	. 754	. 828	. 3
. 002330	98. 5	1200	255	186	. 0319	. 0309	. 813	. 838	. 4
. 002330	98. 7	1250	292	210	. 0332	. 0326	. 781	. 796	. 4
. 002330	97. 9	1120	187	118	. 0231	. 0260	. 861	. 766	0
. 002325	98. 5	1195	244	171	. 0296	. 0300	. 819	. 810	. 3
. 002325	98. 4	1145	202	145	. 0273	. 0270	. 851	. 863	+. 3
. 002325	97. 9	1040	127	78	. 0179	. 0210	. 931	. 806	0
. 002325	97. 8	1000	97	48	. 0118	. 0170	. 968	. 671	0
. 002325	97. 8	945	50	17	. 0047	. 0098	1. 025	. 494	−. 6
. 002325	97. 8	880	15	−17	−. 0054	. 0034	1. 1055	−1. 636	−. 3
. 002325	97. 1	860	−4	−30	−. 0100	−. 0014	1. 1235	−. 800	−. 1
. 002335	74. 5	1390	527	511	. 0654	. 0477	. 531	. 726	+. 5
. 002335	74. 7	1395	532	522	. 0664	. 0476	. 530	. 740	. 4
. 002340	70. 2	1385	537	540	. 0692	. 0488	. 502	. 717	. 5
. 002340	70. 5	1385	537	543	. 0695	. 0488	. 507	. 719	. 1
. 002340	62. 9	1375	547	568	. 0738	. 0504	. 453	. 663	+. 5
. 002340	62. 7	1375	547	564	. 0734	. 0504	. 452	. 658	−. 4
. 002345	52. 7	1370	547	615	. 0804	. 0507	. 381	. 603	+. 6
. 002345	54. 2	1375	549	609	. 0791	. 0502	. 390	. 616	----------
. 002350	19. 5	1380	547	736	. 0950	. 0502	. 1400	. 266	. 8
. 002350	19. 2	1375	542	736	. 0955	. 0498	. 1385	. 266	. 6

TABLE I—Continued

23° AT 42″

ρ	V M. P. H.	P. M. R.	Q lb. ft.	T lb.	C_T	C_P	$\frac{V}{nD}$	η	Def. at 42″ Rad., degrees
0.002360	81.2	1230	546	452	0.0732	0.0625	0.653	0.763	+0.8
.002360	81.0	1230	547	453	.0733	.0625	.652	.763	.5
.002355	87.6	1235	539	436	.0704	.0616	.701	.801	.6
.002355	87.3	1250	544	436	.0685	.0604	.690	.783	.6
.002355	96.0	1275	542	419	.0635	.0577	.745	.820	.0
.002355	95.5	1275	542	418	.0630	.0577	.741	.810	.2
.002345	99.5	1290	539	413	.0611	.0562	.763	.831	.4
.002345	99.5	1295	541	412	.0605	.0562	.761	.820	+.2
.002345	97.5			−21					−.2
.002345	97.7	750	7	−14	−.0063	.0022	1.290	−.378	−.2
.002345	98.0	825	68	+27	.0098	.0173	1.175	.664	+.3
.002345	98.5	875	107	54	.0173	.0244	1.115	.794	.5
.002340	98.8	890	123	64	.0201	.0271	1.105	.816	+.3
.002340	99.1	975	192	112	.0290	.0350	1.005	.834	−.3
.002330	96.2	935	175	101	.0283	.0348	1.025	.834	+.4
.002335	99.6	1025	238	151	.0355	.0407	.963	.840	.0
.002335	99.5	995	213	131	.0327	.0375	.990	.864	.2
.002335	99.0	1055	277	181	.0402	.0436	.930	.858	.5
.002335	99.5	1170	397	282	.0509	.0509	.843	.843	.0
.002330	98.3	1135	367	249	.0476	.0500	.866	.824	.6
.002330	98.8	1090	307	201	.0421	.0452	.898	.836	−.2
.002330	100.0	1195	422	305	.0528	.0519	.830	.846	+.3
.002330	100.0	1235	467	344	.0561	.0538	.801	.836	.2
.002325	99.5	1265	502	374	.0580	.0550	.780	.823	−.7
.002325	100.5	1290	532	413	.0618	.0562	.771	.849	−.3
.002325	98.3	925	147	85	.0248	.0302	1.050	.862	.0
.002335	75.0	1215	537	462	.0777	.0638	.612	.745	−.2
.002335	74.6	1215	537	463	.0778	.0638	.615	.750	+.4
.002340	69.1	1210	537	475	.0801	.0642	.565	.707	.5
.002340	69.4	1210	536	478	.0805	.0642	.568	.713	.5
.002340	64.5	1205	537	498	.0846	.0645	.530	.695	.8
.002340	65.1	1205	537	499	.0858	.0645	.534	.711	.8
.002340	61.6	1200	537	512	.0875	.0648	.508	.686	.4
.002340	60.5	1205	539	513	.0870	.0648	.498	.668	.8
.002350	18.5	1180	537	547	.0968	.0670	.155	.224	.3
.002350	17.7	1185	538	548	.0962	.0666	.148	.214	.5

TABLE I—Continued

27° AT 42″

ρ	V M. P. H.	N R. P. M.	Q lb. ft.	T lb.	C_T	C_P	$\frac{V}{nD}$	η	Def. at 42″ Rad., degrees
0. 002325	81. 2	1075	537	388	0. 0832	0. 0817	0. 748	0. 762	+0. 1
. 002325	80. 9	1075	534	386	. 0829	. 0813	. 744	. 758	+. 1
. 002325	86. 1	1085	537	380	. 0800	. 0801	. 785	. 783	−. 1
. 002325	86. 1	1090	537	379	. 0792	. 0793	. 781	. 780	+. 1
. 002320	95. 1	1115	538	361	. 0721	. 0762	. 843	. 798	. 3
. 002320	95. 4	1120	538	361	. 0714	. 0754	. 842	. 797	. 2
. 002315	99. 5	1130	539	356	. 0694	. 0745	. 871	. 810	+. 1
. 002315	99. 5	1130	539	357	. 0695	. 0745	. 871	. 812	−. 1
. 002315	99. 1	1105	516	337	. 0688	. 0743	. 888	. 821	+. 1
. 002315	99. 3	1065	457	289	. 0634	. 0711	. 922	. 822	. 1
. 002310	99. 0	1020	412	251	. 0606	. 0700	. 960	. 831	1. 6
. 002305	99. 3	1000	382	231	. 0577	. 0676	. 982	. 837	. 6
. 002305	98. 7	960	333	195	. 0528	. 0640	1. 017	. 839	+. 4
. 002305	98. 6	920	289	164	. 0484	. 0603	1. 060	. 851	−. 1
. 002305	98. 3	855	215	118	. 0403	. 0520	1. 138	. 884	−. 2
. 002305	98. 1	820	179	91	. 0340	. 0472	1. 184	. 853	−. 2
. 002305	97. 9	780	137	60	. 0246	. 0398	1. 244	. 769	+. 2
. 002305	97. 3	730	97	39	. 0183	. 0322	1. 321	. 750	−. 2
. 002305	97. 8	680	39	7	. 0038	. 0150	1. 424	. 359	+. 1
. 002305	97. 8	630	−8	−20	−. 0126	−. 0036	1. 537	----------	−. 1
. 002305	98. 3	885	247	138	. 0440	. 0560	1. 100	. 864	+. 2
. 002315	75. 0	1075	541	408	. 0881	. 0828	. 691	. 736	. 1
. 002315	74. 5	1075	537	408	. 0881	. 0817	. 686	. 741	+. 2
. 002317	67. 8	1075	537	418	. 0900	. 0817	. 623	. 687	−. 1
. 002317	67. 8	1075	535	420	. 0904	. 0816	. 623	. 691	+. 2
. 002317	64. 5	1070	536	424	. 0920	. 0828	. 595	. 660	+. 2
. 002317	64. 2	1065	536	425	. 0934	. 0830	. 595	. 670	−. 1
. 002317	54. 1	1080	542	438	. 0936	. 0817	. 495	. 567	+. 2
. 002317	55. 0	1080	542	435	. 0929	. 0817	. 504	. 574	. 1
. 002325	14. 2	1010	535	402	. 0975	. 0921	. 139	. 147	. 1
. 002325	14. 2	1010	538	402	. 0951	. 0907	. 138	. 144	. 1

TABLE II

FINAL ADJUSTED COEFFICIENTS

(PROP. No. 4412)

(BLADE ANGLE 11° at 42″ r.)

$\frac{V}{nD}$	C_T	C_P	η	C_S
0.15	0.0652	0.0263	0.372	0.309
.20	.0601	.0260	.462	.416
.25	.0549	.0254	.540	.521
.30	.0492	.0243	.607	.631
.35	.0434	.0230	.660	.744
.40	.0373	.0214	.698	.864
.45	.0312	.0194	.724	.990
.50	.0250	.0172	.726	1.125
.55	.0186	.0147	.688	1.279
.60	.0116	.0118	.590	1.458
.65	.0041	.0097	.275	1.644

TABLE II—Continued

15° AT 42″

$\frac{V}{nD}$	C_T	C_P	η	C_S
0.15	0.0831	0.0371	0.336	0.295
.20	.0788	.0379	.416	.385
.25	.0740	.0380	.487	.482
.30	.0690	.0373	.555	.580
.35	.0635	.0364	.611	.679
.40	.0580	.0348	.667	.783
.45	.0521	.0330	.711	.891
.50	.0461	.0310	.745	1.002
.55	.0400	.0287	.766	1.118
.60	.0338	.0260	.780	1.248
.65	.0275	.0226	.790	1.388
.70	.0212	.0190	.781	1.546
.75	.0149	.0154	.725	1.726
.80	.0081	.0112	.578	1.96

TABLE II—Continued

19° AT 42″

$\frac{V}{nD}$	C_T	C_P	η	C_S
0.15	0.0948	0.0503	0.283	0.269
.20	.0922	.0508	.363	.364
.25	.0896	.0510	.440	.454
.30	.0861	.0510	.506	.544
.35	.0826	.0510	.568	.635
.40	.0785	.0508	.619	.727
.45	.0741	.0501	.666	.819
.50	.0691	.0489	.708	.914
.55	.0639	.0469	.750	1.012
.60	.0581	.0445	.785	1.118
.65	.0520	.0419	.807	1.227
.70	.0455	.0388	.820	1.340
.75	.0389	.0352	.829	1.465
.80	.0322	.0313	.823	1.600
.85	.0259	.0271	.812	1.750
.90	.0194	.0230	.759	1.912
.95	.0131	.0186	.669	2.11
1.00	.0070	.0136	.515	2.36

TABLE II—Continued

23° AT 42″

$\frac{V}{nD}$	C_T	C_P	η	C_S
0.15	0.0969	0.0669	0.218	0.257
.20	.0963	.0666	.289	.344
.25	.0959	.0663	.361	.431
.30	.0950	.0660	.432	.516
.35	.0940	.0658	.500	.603
.40	.0926	.0654	.567	.690
.45	.0905	.0650	.626	.779
.50	.0876	.0649	.675	.864
.55	.0832	.0645	.710	.952
.60	.0787	.0639	.740	1.040
.65	.0736	.0626	.765	1.131
.70	.0682	.0603	.792	1.236
.75	.0623	.0573	.815	1.329
.80	.0565	.0540	.838	1.434
.85	.0502	.0502	.850	1.545
.90	.0440	.0461	.857	1.665
.95	.0372	.0418	.845	1.790
1.00	.0310	.0369	.840	1.936
1.05	.0249	.0319	.819	2.09
1.10	.0186	.0264	.776	2.27
1.15	.0122	.0209	.671	2.49
1.20	.0060	.0152	.474	2.76

TABLE II—Continued

27° AT 42″

$\frac{V}{nD}$	C_T	C_P	η	C_S
0.15	0.0962	0.0911	0.158	0.240
.20	.0956	.0890	.215	.324
.25	.0950	.0869	.274	.409
.30	.0944	.0850	.333	491
.35	.0940	.0834	.394	.576
.40	.0934	.0821	.455	.660
.45	.0932	.0814	.516	.744
.50	.0930	.0812	.572	.826
.55	.0930	.0817	.626	.908
.60	.0925	.0821	.675	.988
.65	.0900	.0823	.711	1.072
.70	.868	.0820	.741	1.154
.75	.826	.0819	.758	1.237
.80	.776	.0789	.788	1.330
.85	.721	.0761	.805	1.425
.90	.666	.0729	.823	1.520
.95	.610	.0694	.835	1.620
1.00	.552	.0655	.844	1.726
1.05	.497	.0611	.855	1.835
1.10	.439	.0560	.862	1.958
1.15	.380	.0507	.861	2.08
1.20	.319	.0450	.852	2.23
1.25	.258	.0393	.822	2.39
1.30	.196	.0334	.762	2.56
1.35	.132	.0271	.658	2.77
1.40	.0068	.0202	.471	3.05